

# NEWS & VIEWS

## Turning off the lights: Supernova SN1987A 30 years on

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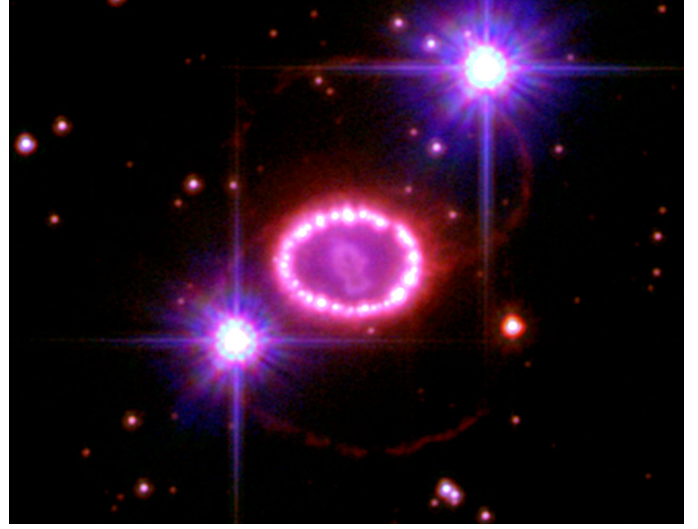
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**Decades-long repeat observations of supernova SN1987A offer us unique, real-time insights into the violent death of a massive star and its long-term environmental effects, until its eventual switch-off.**

On 23 February 1987, supernova SN1987A—the explosive last gasps of a dying massive star—suddenly illuminated the Large Magellanic Cloud. Such bright stellar explosions occur only once or twice per century in large spiral galaxies like our Milky Way and much less frequently in Magellanic-type dwarf galaxies. At a distance of 163,000 light-years<sup>1</sup>, SN1987A was the closest recorded supernova since Kepler’s Supernova in 1604 and Cassiopeia A in the late-17<sup>th</sup> Century, both of which occurred in the Milky Way. Fortunately, we now have access to cutting-edge astronomical facilities, thus allowing us to monitor the explosion and subsequent evolution of the entire SN1987A system in real time.

In a recent article in *The Astrophysical Journal Letters*, Fransson *et al.*<sup>2</sup> present a 20-year timeline of changes in the appearance of the supernova’s complex system of rings. Two of these rings are most likely caused by mass outflows from its red supergiant progenitor star up to 20,000 years before the explosion<sup>3</sup>. The brighter but smaller inner ring, on the other hand, was generated by interactions of the progenitor’s swept-up stellar wind with the ambient gas. Hubble Space Telescope observations have enabled us to witness the appearance and subsequent disappearance of ‘hot spots’ along this latter circumstellar ring. These are likely caused by interactions of the densest gas clumps in the circumstellar gas with the supernova’s outward-propagating blast wave, thus leading to the appearance of a ring-like shape. The expanding supernova debris left behind after the blast wave passed by is decelerated by a ‘reverse shock’, which is due to electrons cascading down to lower energy levels following collisional excitation of neutral hydrogen atoms, triggered when the debris crosses the shock front.

Until approximately 2009, the observational timeline of Fransson *et al.*<sup>2</sup> shows an exponentially increasing contribution to the hot spots from shocked emission and outward acceleration of these clumps of up to 700–1000 km s<sup>−1</sup>. New hot spots and faint, diffuse emission have since appeared outside of the now-fading inner ring. These new hot spots could have been triggered by the expanding blast wave if the density of the interstellar clumps was sufficiently high for the pressure from the reverse shock to cause cooling by radiating away heat. This, in turn, would cause the clumps to collapse into an even smaller volume and emit optically visible radiation<sup>4</sup>. Ionization of the original stellar-wind ejecta caused by X-ray emission originating from lower-density material behind the expanding shock wave may be responsible for the



**Figure 1** | Optical Hubble Space Telescope image of SN1987A taken in December 2006 with the Advanced Camera for Surveys. (Credit: NASA, ESA, and R. Kirshner, Harvard–Smithsonian Center for Astrophysics)

diffuse emission.

The authors<sup>2</sup> interpret the decrease in optical emission in the inner ring since 2013 as evidence of its dissolution. They deduce that the most likely reason for this decrease is that the area affected by shocks generating bright optical radiation is getting smaller. Alternatively, the expected steeply outward-increasing radial density distribution of the stellar-wind material<sup>5,6</sup> implies a corresponding increasing density threshold for clumps to sustain such radiative shocks. Either of these scenarios will lead to instabilities in the hot spots, conduction by the ambient hot gas and, consequently, rapid dissolution of the densest clumps<sup>4</sup>. Fransson *et al.*<sup>2</sup> predict that the inner ring will likely be fully destroyed within the next 10 years.

SN1987A thus provides unprecedented insights into the physical properties of its massive progenitor from a perspective that is unavailable elsewhere. The system’s impact goes well beyond this immediate application. We can, in principle, also use the maximum observed angular size of the ring, combined with the speed of light and accurate delay-time measurements, to independently obtain a reliable geometric distance to the supernova. However, since the ring is resolved, we need to consider whether the emission used to measure delay times at a variety of wavelengths actually originates from the same region(s) in the ring. For instance, the ring size measured using optical emission from doubly ionized oxygen atoms<sup>7</sup> is significantly different from that traced by ultraviolet lines<sup>8</sup>. It has been suggested that the latter orig-

inate from the ring’s inner edge, whereas the optical lines come from its main body. In this case, and using the proper geometry, including a finite ring thickness, the ultraviolet light curve could result in an underestimate of the light-travel time across the optical ring diameter of up to 7% and, thus, a similar underestimate of the distance<sup>9</sup>.

We also need to consider potential errors caused by a misinterpretation of the underlying physics. Most importantly, it is often assumed that the fluorescent, scattered emission from the interstellar gas commences as soon as the supernova’s energetic photons hit a gas cloud. It is possible, though, that there is a slight delay in the onset of fluorescent emission as the gas first recombines from highly ionized states, for instance. Neglecting this step will lead to ring-size and, hence, distance overestimates.

SN1987A will likely become more X-ray and less hot-spot dominated as the system continues to evolve<sup>2</sup>. The high-resolution Hubble Space Telescope observations of Fransson *et al.*<sup>2</sup> and their spectroscopic analysis will allow us to settle the system’s full evolution unequivocally and provide the tightest geometric constraints yet on the use of resolved supernovae as distance tracers. As the important first rung of the extragalactic distance ladder, the importance of reducing the systematic uncertainties in the distance to the Large Magellanic Cloud cannot be overstated<sup>1</sup>.

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